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ATTORNEY'S DOCKET NUMBER
111970

**TRANSMITTAL LETTER TO THE
UNITED STATES
DESIGNATED/ELECTED OFFICE
(DO/EO/US) CONCERNING A FILING
UNDER 35 U.S.C. 371**

U.S. APPLICATION NO.
(if known, sec 37 C.F.R 1 5)

10/049816

INTERNATIONAL APPLICATION NO.
PCT/JP00/06683

INTERNATIONAL FILING DATE
September 27, 2000

PRIORITY DATE CLAIMED
September 28, 1999

TITLE OF INVENTION
COOLANT, METHOD OF ENCLOSING COOLANT, AND COOLING SYSTEM

APPLICANTS FOR DO/EO/US

Mikito NISHII, Masamine TANIKAWA, Hisanori WATANABE, Yoshihisa KUROKAWA, Satoshi SUGIYAMA, Kazuhito YAEDA

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventors (35 U.S.C. 371(c)(4)).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ Entitlement to small entity status is hereby asserted.
16. ☐ Other items or information:

U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5) 10/049816		INTERNATIONAL APPLICATION NO. PCT/JP00/06683		ATTORNEY'S DOCKET NUMBER 111970	
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17. <input checked="" type="checkbox"/> The following fees are submitted: Basic National fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO\$890.00 International preliminary examination fee paid to USPTO (37 CFR1.482)\$710.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))\$740.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO\$1,040.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)\$ 100.00 ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS		PTO USE ONLY	
				\$890.00			
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$			
Claims	Number Filed	Number Extra	Rate				
Total Claims	17- 20 =	0	X \$ 18.00	\$			
Independent Claims	2- 3 =	0	X \$ 84.00	\$			
Multiple dependent claim(s)(if applicable)			+ \$280.00	\$			
TOTAL OF ABOVE CALCULATIONS =				\$890.00			
Reduction by 1/2 for filing by small entity, if applicable.				-			
SUBTOTAL =				\$890.00			
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 month from the earliest claimed priority date (37 CFR 1.492(f)).				\$			
TOTAL NATIONAL FEE =				\$890.00			
				Amount to be refunded			
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a. ☒ Check No. 127913 in the amount of \$890.00 to cover the above fees is enclosed.

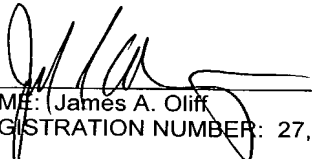
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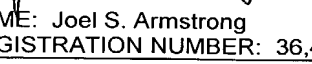
c. ☒ The Director is hereby authorized to charge any additional fees which may be required, or credit any overpayment, to Deposit Account No. 15-0461. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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Date: February 19, 2002


 NAME: James A. Oliff
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 REGISTRATION NUMBER: 36,430

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Mikito NISHII, Masamine TANIKAWA,
Hisanori WATANABE, Yoshihisa KUROKAWA,
Satoshi SUGIYAMA, Kazuhito YAEDA

Application No.: U.S. National Stage
of PCT/JP00/06683

Filed: February 19, 2002

Docket No.: 111970

For: COOLANT, METHOD OF ENCLOSING COOLANT, AND COOLING SYSTEM

PRELIMINARY AMENDMENT

Director of the U.S. Patent and Trademark Office
Washington, D. C. 20231

Sir:

Prior to initial examination, and after entry of the Annexes to the IPER please amend the above-identified application as follows:

IN THE CLAIMS:

Please replace claims 3-4, 7-10 and 13-16 as follows:

3. (Amended) A coolant for fuel cells in accordance with claim 1, wherein the rust-preventive additive includes at least one of an alkalescent additive and an acidulous additive.
4. (Amended) A coolant for fuel cells in accordance with claim 1, wherein the rust-preventive additive includes an alkaline additive and an acidic additive.
7. (Amended) A coolant for fuel cells in accordance with claim 4, wherein the acidic additive is selected out of the group consisting of triazole compounds, phosphoric acid compounds, and organophosphoric acid compounds.

8. (Amended) A coolant for fuel cells in accordance with claim 1, wherein the rust-preventive additive causes said coolant for fuel cells to have a hydrogen ion exponent of about 6 to 9.

9. (Amended) A coolant for fuel cells in accordance with claim 1, wherein the rust-preventive additive causes said coolant for fuel cells to have a low electric conductivity of less than about 100 $\mu\text{S}/\text{cm}$.

10. (Amended) A coolant for fuel cells in accordance with claim 1, wherein the rust-preventive additive especially has rust-preventive performance against aluminum material.

13. (Amended) A coolant in accordance with claim 11, said coolant is decontaminated by a coolant decontamination system using either one of an ion exchange resin and a chelating resin.

14. (Amended) A coolant in accordance with claim 1, said coolant has undergone deoxidization.

15. (Amended) A method of enclosing a coolant in accordance with claim 1 in a cooling circuit for a stack of fuel cells, said method comprising the steps of: deoxidizing said coolant; and enclosing said deoxidized coolant with an inert gas in said cooling circuit.

16. (Amended) A cooling system for a stack of fuel cells, said cooling system comprising: a coolant in accordance with claim 1; and a cooling circuit in which said coolant and an inert gas are enclosed.

REMARKS

Claims 1-17 are pending. By this Preliminary Amendment, claims 3-4, 7-10 and 13-16 are amended to eliminate multiple dependencies. Prompt and favorable examination on the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten claim (37 C.F.R. §1.121(c)(1)(ii)).

Respectfully submitted,


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JAO:JSA/cmm

Attachment: Appendix

Date: February 19, 2002

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<p>DEPOSIT ACCOUNT USE AUTHORIZATION Please grant any extension necessary for entry; Charge any fee due to our Deposit Account No. 15-0461</p>
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APPENDIX

Changes to Claims:

The following are marked-up versions of the amended claims:

3. (Amended) A coolant for fuel cells in accordance with claim 1 ~~either one of claims 1 and 2~~, wherein the rust-preventive additive includes at least one of an alkalescent additive and an acidulous additive.
4. (Amended) A coolant for fuel cells in accordance with claim 1 ~~either one of claims 1 and 2~~, wherein the rust-preventive additive includes an alkaline additive and an acidic additive.
7. (Amended) A coolant for fuel cells in accordance with claim 4 ~~any one of claims 4 to 6~~, wherein the acidic additive is selected out of the group consisting of triazole compounds, phosphoric acid compounds, and organophosphoric acid compounds.
8. (Amended) A coolant for fuel cells in accordance with claim 1 ~~any one of claims 1 to 7~~, wherein the rust-preventive additive causes said coolant for fuel cells to have a hydrogen ion exponent of about 6 to 9.
9. (Amended) A coolant for fuel cells in accordance with claim 1 ~~any one of claims 1 to 8~~, wherein the rust-preventive additive causes said coolant for fuel cells to have a low electric conductivity of less than about 100 $\mu\text{S}/\text{cm}$.
10. (Amended) A coolant for fuel cells in accordance with claim 1 ~~any one of claims 1 to 9~~, wherein the rust-preventive additive especially has rust-preventive performance against aluminum material.
13. (Amended) A coolant in accordance with claim 11 ~~either one of claims 11 and 12~~, said coolant is decontaminated by a coolant decontamination system using either one of an ion exchange resin and a chelating resin.

16. (Amended) A cooling system for a stack of fuel cells, said cooling system comprising: a coolant in accordance with claim 1 ~~any one of claims 1 to 13~~; and a cooling circuit in which said coolant and an inert gas are enclosed.

6/p.12

SPECIFICATION

COOLANT, METHOD OF ENCLOSING COOLANT, AND COOLING SYSTEM

5 Technical Field

The present invention relates to a coolant, a method of enclosing a coolant, and a cooling system utilizing a coolant. More specifically the present invention relates to a coolant for cooling a stack of fuel cells, a method of enclosing a coolant in a cooling circuit of a fuel cells cooling system, and a cooling system for a stack of fuel cells.

Background Art

A stack of fuel cells generally has a laminate structure of multiple unit cells. One cooling plate is disposed between each pair of adjoining sub-stacks, each sub-stack consisting of plural unit cells, to cool the stack (unit cells). A flow path of a coolant is formed in the cooling plate, and the flow of the coolant through the coolant flow path cools down the stack. The coolant for the fuel cells is circulated in the stack that carries out power generation, that is, between each pair of adjoining sub-stacks. In order to prevent a decrease in power generation efficiency (that is, to reduce energy loss) due to the leak to the outside of the stack and the resistance of the coolant, the coolant is required to have high insulation performance. The prior art technique applies pure water for the coolant, in order to satisfy the requirements of ensuring the sufficient insulation performance and the sufficient cooling efficiency. The coolant for the stack of fuel cells is further required to have rust resistance, with a view to extending the life of the cooling plates. The general countermeasure to meet this requirement applies stainless steel material having high rust resistance for the cooling plates. Another proposed technique adds iron ions to the coolant as discussed in JAPANESE PATENT LAID-OPEN GAZETTE No. 2-21572.

Such proposed techniques have effects on the stationary, installed medium-sized or large-sized fuel cells and the continuous-driving fuel cells, but do not have sufficient effects on the portable small-sized fuel cells and the intermittent-driving fuel cells, such as fuel cells mounted on the vehicle.

5 In the case of the intermittent-driving, portable fuel cells, the coolant in the non-working state is cooled down to the environmental temperature. The coolant is accordingly required to have unfreezing performance under the condition that the environmental temperature is below the freezing point. Freezing the coolant may damage a cooling
10 circuit including the cooling plates. The damaged cooling circuit may lead to insufficient performances of the fuel cells.

In order to ensure the unfreezing performance, a coolant for cooling an internal combustion engine may be used as the unfreezing coolant. The coolant for cooling the internal combustion engine is, however,
15 intrinsically used in the parts with no power generation and is not required to have low electric conductivity. Namely such a coolant has extremely high electric conductivity. The electric current flows through a cooling pipe in the stack of fuel cells. The high electric conductivity of the coolant accordingly causes the power generated by the fuel cells to flow into the
20 coolant. This leads to an undesirable power loss. The coolant for cooling the internal combustion engine is accordingly unsuitable as the coolant for cooling the stack of fuel cells.

In the case of the portable fuel cells mounted on the vehicle, reduction in total weight of a fuel cells system including the cooling circuit
25 is an important issue. For the purpose of reduction in weight, it is expected to use a light metal having high heat conductivity, such as aluminum material, for the cooling plates and a heat exchanger. The light metal, however, generally does not have so high rust resistance as that of the stainless steel material, so that the coolant itself is required to have
30 rust resistance.

The object of the present invention is thus to solve the problems of the prior art techniques discussed above and to provide a coolant for a stack of fuel cells having low electric conductivity, rust-preventing ability, high transmission ability, and unfreezing performance.

5

Disclosure of the Invention

In order to attain the above and the other related objects, a first application of the present invention is a coolant including: a water-containing base material; and a rust-preventive additive that functions to
10 keep an electric conductivity of the coolant at a low level and to maintain a hydrogen ion exponent of the coolant in a substantially neutral level.

The first application of the present invention gives the coolant satisfying the required low electric conductivity, rust-preventing ability, high transmission ability, and unfreezing performance.

15 In the coolant according to the first application of the present invention, the base material may be a solution mixture containing a glycol. The rust-preventive additive may include at least one of an alkalescent additive and an acidulous additive, or may include an alkaline additive and an acidic additive. The alkaline additive may be an ethanolamine. The
20 ethanolamine may include triethanolamine, diethanolamine, and monoethanolamine.

In one preferable embodiment of the coolant according to the first application of the present invention, the acidic additive is selected out of the group consisting of triazole compounds, phosphoric acid compounds,
25 and organophosphoric acid compounds. The rust-preventive additive may cause the coolant to have a hydrogen ion exponent of about 6 to 9, or may cause the coolant to have a low electric conductivity of less than about 100 $\mu\text{S}/\text{cm}$. It is preferable that the rust-preventive additive especially has rust-preventive performance against aluminum material.

30 In another preferable embodiment of the coolant according to the

first application of the present invention, the rust-preventive additive is a nonionic substance. The nonionic substance may be at least one of a saccharide and a nonionic surfactant. It is preferable that the coolant is decontaminated by a coolant decontamination system using either one of
5 an ion exchange resin and a chelating resin. The coolant may have undergone deoxidization. In the case where a nonionic substance is used as the rust-preventive additive, the rust-preventive additive is not ionized in the coolant. The ion exchange resin or the chelating resin is applied to easily remove only the ionized impurities. The deoxidization effectively
10 prevents deterioration of the quality of the coolant over a long time period.

A second application of the present invention is a method of enclosing the coolant according to the first application of the present invention in a cooling circuit for a stack of fuel cells. This method includes the steps of: deoxidizing the coolant; and enclosing the deoxidized coolant
15 with an inert gas in the cooling circuit.

The second application of the present invention effectively prevents deterioration of the quality of the coolant in the cooling circuit over a long time period.

A third application of the present invention is a cooling system for a
20 stack of fuel cells. The cooling system includes: the coolant according to the first application of the present invention; and a cooling circuit in which the coolant and an inert gas are enclosed.

The cooling system according to the third application of the present invention attains the required low electric conductivity, rust-preventing
25 ability, high transmission ability, and unfreezing performance. This arrangement effectively prevents deterioration of the quality of the coolant in the cooling circuit over a long time period.

A fourth application of the present invention is a method of decontaminating a coolant. The method according to the fourth
30 application of the present invention includes the steps of: preparing a

water-containing base material; preparing a rust-preventive additive that functions to keep an electric conductivity of the coolant at a low level and to maintain a hydrogen ion exponent of the coolant in a substantially neutral level; and removing only deteriorating substances from the coolant, which is obtained by mixing the rust-preventive additive with the base material, with either one of an ion exchange resin and a chelating resin at regular intervals.

The method of decontaminating a coolant according to the fourth application of the present invention effectively prevents deterioration of the quality of the coolant, which satisfies the required low electric conductivity, rust-preventing ability, high transmission ability, and unfreezing performance, over a long time period. One of glycols may be used in addition to water for the base material. One of nonionic substances may be used for the rust-preventive additive.

Brief Description of the Drawings

Fig. 1 is a table showing the composition and hydrogen ion exponent (pH) of diverse coolants used as Examples 1 through 9 according to the present invention and the composition and pH of other coolants used as Comparative Examples 1 through 6;

Fig. 2 is a table showing results of various tests with regard to Examples 1 through 9 and Comparative Examples 1 through 6 enumerated in Fig. 1;

Fig. 3 is a graph showing a variation in electric conductivity due to addition of quercetin to a 50% diluted solution of ethylene glycol;

Fig. 4 illustrates the structure of a fuel cells stack cooling system in a second embodiment of the present invention;

Fig. 5 is a decomposed perspective view showing the stack structure of unit cells 20; and

Fig. 6 schematically illustrates a process flow of manufacturing a

coolant according to a first embodiment by a method in a third embodiment of the present invention.

Best Modes of Carrying Out the Invention

5 * First Embodiment:

The following describes coolants according to the present invention with reference to Figs. 1 and 2.

The characteristics of various coolants are discussed first with referring to Fig. 1. Fig. 1 is a table showing the composition and hydrogen ion exponent (pH) of diverse coolants used as Examples 1 through 9 according to the present invention and the composition and pH of other coolants used as Comparative Examples 1 through 6. Fig. 2 is a table showing results of various tests performed on the coolants of Examples 1 through 9 and Comparative Examples 1 through 6 enumerated in Fig. 1. In the table of Fig. 1, Examples 1 through 9 are expressed as Ex. 1 to Ex. 9.

The coolant of Example 1 includes ethylene glycol (50% by weight) and ion exchanged water (48.9% by weight) as base material and triethanolamine (1.0% by weight) and ortho-phosphoric acid (0.1% by weight) as rust-preventive additives. Ethylene glycol, as well as propylene glycol, is one of glycols and is known as the substance that gives unfreezing properties to a solution mixture. The solution mixture of ion exchanged water and a glycol used as the base material has excellent heat conductivity, as clearly understood from the fact that this solution mixture is generally used as the coolant for internal combustion engines of vehicles.

Triethanolamine, one of ethanolamines, is an alkaline rust-preventive agent, whereas ortho-phosphoric acid, one of phosphoric acid compounds, is an acidic rust-preventive agent. The coolant of Example 1 has pH of 8.1. In order to ensure the sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of triethanolamine is 0.1 to 3.0% by weight, and the allowable

addition range of ortho-phosphoric acid is 0.1 to 1.0% by weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water. Another ethanolamine, such as monoethanolamine or diethanolamine, may replace triethanolamine, whereas another phosphoric acid compound may replace ortho-phosphoric acid.

The coolant of Example 2 includes ethylene glycol (50% by weight) and ion exchanged water (49.655% by weight) as base material and triethanolamine (0.34% by weight) and phosphonic acid (0.005% by weight) as rust-preventive additives. Phosphonic acid, one of organophosphoric acid compounds, is an acidic rust-preventive agent. The coolant of Example 2 has pH of 8.1. In order to ensure the sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of triethanolamine is 0.1 to 3.0% by weight, and the allowable addition range of phosphonic acid is 0.001 to 0.01% by weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water. Another ethanolamine, such as monoethanolamine or diethanolamine, may replace triethanolamine, whereas another organophosphoric acid compound may replace ortho-phosphoric acid.

The coolant of Example 3 includes ethylene glycol (50% by weight) and ion exchanged water (49.9% by weight) as base material and benzotriazole (0.1% by weight) as a rust-preventive additive. Benzotriazole, one of triazole compounds, is an acidic rust-preventive agent. The coolant of Example 3 has pH of 6.2. In order to ensure the sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of benzotriazole is 0.1 to 0.6% by weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water. Another triazole may replace benzotriazole.

The coolants of Examples 4 to 9 discussed below are characterized by application of nonionic substances, which are not ionized in aqueous solutions, for the rust-preventive agent. The nonionic substances include saccharides and nonionic surfactants.

5 The coolant of Example 4 includes ethylene glycol (50% by weight) and ion exchanged water (49.95% by weight) as base material and quercetin (3,3',4',5,7-pentahydroxyflavone) (0.05% by weight), which is a nonionic substance and one of glycosides, as a rust-preventive additive. The coolant of Example 4 has pH of 7 to 8. In order to ensure the
10 sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of quercetin is 0.005 to 0.2% by weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water.

The coolant of Example 5 includes ethylene glycol (50% by weight)
15 and ion exchanged water (49.90% by weight) as base material and glucose (0.10% by weight), which is one of monosaccharides, as a rust-preventive additive. The coolant of Example 5 has pH of 7 to 8. In order to ensure the sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of glucose is 0.05 to 0.5% by
20 weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water.

The coolant of Example 6 includes ethylene glycol (50% by weight) and ion exchanged water (49.90% by weight) as base material and maltose (0.10% by weight), which is one of oligosaccharides, as a rust-preventive
25 additive. The coolant of Example 6 has pH of 7 to 8.

The coolant of Example 7 includes ethylene glycol (50% by weight) and ion exchanged water (49.50% by weight) as base material and maltose (0.50% by weight), which is one of oligosaccharides, as a rust-preventive additive. The coolant of Example 7 has pH of 7 to 8.

30 The coolant of Example 8 includes ethylene glycol (50% by weight)

and ion exchanged water (49.90% by weight) as base material and alkyl glucoside (0.10% by weight), which is one of nonionic surfactants, as a rust-preventive additive. The coolant of Example 8 has pH of 7 to 8. In order to ensure the sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of alkyl glucoside is 0.05 to 0.5% by weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water.

The coolant of Example 9 includes ethylene glycol (50% by weight) and ion exchanged water (49.90% by weight) as base material and polyoxyethylene (POE) sorbitan monopalmitate (0.10% by weight), which is one of nonionic surfactants, as a rust-preventive additive. The coolant of Example 9 has pH of 7 to 8. In order to ensure the sufficient rust-preventive performance and suppress the electric conductivity, the allowable addition range of POE sorbitan monopalmitate is 0.05 to 0.5% by weight. In this example, the total composition is adjusted to 100% by weight by regulating the percent by weight of ion exchanged water.

In fuel cells mounted on a vehicle, aluminum or an aluminum alloy is generally used as the material of cooling panels and a heat exchanger in a cooling circuit. The embodiment of the present invention thus gives specific consideration to corrosion resistance to the aluminum-containing materials. Reduction in weight and cost is required for the fuel cells mounted on the vehicle. The aluminum material, which is widely applied for car radiators, is expected as the suitable material that fulfills such requirements.

The respective rust-preventive additives used in Examples 1 to 9 are only illustrative, but any rust-preventive agents having favorable rust-preventive performances against the aluminum material. In the case of selection of a material other than the aluminum material, a rust-preventive agent having rust-preventive performance against the selected material

should be used.

The coolant of Comparative Example 1 is a coolant generally used for cooling internal combustion engines of automobiles, and includes ethylene glycol (50% by weight) and ion exchanged water (46.78% by weight) as base material and ortho-phosphoric acid (0.2% by weight), benzotriazole (0.1% by weight), sodium nitrate (0.1% by weight), sodium molybdate (0.2% by weight), sodium benzoate (2.5% by weight), and sodium hydroxide (0.12% by weight). The coolant of Comparative Example 1 has pH of 7.3.

The coolant of Comparative Example 2 includes ethylene glycol (50% by weight) and ion exchanged water (50% by weight). This was used for discussion on the characteristics of the ethylene glycol-ion exchanged water system without any rust-preventive agent. The coolant of Comparative Example 2 has pH of 6.8.

The coolant of Comparative Example 3 includes propylene glycol (50% by weight) and ion exchanged water (50% by weight). This was used for discussion on the characteristics of the propylene glycol-ion exchanged water system without any rust-preventive agent. The coolant of Comparative Example 3 has pH of 6.8.

The coolant of Comparative Example 4 includes glycerol (50% by weight) and ion exchanged water (50% by weight), and was used for the purpose of comparison.

Comparative Example 5 is typical tap water (100% by weight) and was used for discussion on the characteristics of tap water.

Comparative Example 6 is ion exchanged water (100% by weight) conventionally used as a coolant for cooling fuel cells and was used for the purpose of comparison.

In the respective Examples and Comparative Examples, pH was regulated to the range of 6 to 9 without using any pH regulator (for example, potassium hydroxide) but by controlling the quantity of addition of

the rust-preventive agent. pH was measured with a commercially available pH meter at 25°C.

The results of various tests are discussed with referring to Fig. 2. Fig. 2 is a table showing results of various tests with regard to Examples 1 through 9 and Comparative Examples 1 through 6 enumerated in Fig. 1.

The results of a test for the electric conductivity ($\mu\text{S}/\text{cm}$) are discussed first. The electric conductivity test places two electrodes in each coolant sample and measures the flowability of electric current between the two electrodes. The method of this test is known to those skilled in the art. In the embodiment of the present invention, the electric conductivity was measured with a commercially available conductivity meter under the condition of 25°C. In the table of Fig. 2, Examples 1 through 9 are expressed as Ex.1 to Ex. 9.

The discussion first regards the coolant of Comparative Example 1, which is conventionally used for cooling internal combustion engines of automobiles. The observed electric conductivity of Comparative Example 1 was 5960 ($\mu\text{S}/\text{cm}$), which was extremely higher than the observed values of electric conductivity of the respective Examples and the other Comparative Examples. This is ascribed to the presence of the strong electrolytes, that is, sodium hydroxide and sodium nitrate, as the additives in Comparative Example 1. Even a trace amount of the strong electrolyte significantly raises the electric conductivity. Sodium nitrate, sodium molybdate, and sodium benzoate are generally used rust-preventive agents, whereas sodium hydroxide and potassium hydroxide are generally used neutralizers.

Comparative Example 5 also contains various ions and accordingly showed the relatively high electric conductivity of 286 ($\mu\text{S}/\text{cm}$). Comparative Example 4, on the other hand, hardly contains any ions and accordingly showed the relatively low electric conductivity of 1.8 ($\mu\text{S}/\text{cm}$). Ion exchanged water (Comparative Example 6), which is conventionally

used as a coolant for fuel cells, hardly contains any ions and accordingly showed the lowest electric conductivity of 0.88 ($\mu\text{S}/\text{cm}$).

The coolant of Example 2 showed the electric conductivity of 5.01 ($\mu\text{S}/\text{cm}$). This observed value of electric conductivity was sufficiently
5 close to the electric conductivity 3.46 ($\mu\text{S}/\text{cm}$) of Comparative Example 2, which is the base material of the coolant of Example 2, and is relatively close to the electric conductivity 1.63 ($\mu\text{S}/\text{cm}$) of Comparative Example 3, which contains propylene glycol belonging to the glycols.

The coolant of Example 3 showed the electric conductivity of 2.11
10 ($\mu\text{S}/\text{cm}$). This observed value of electric conductivity was practically similar to the electric conductivity 3.46 ($\mu\text{S}/\text{cm}$) of Comparative Example 2, which is the base material of the coolant of Example 3, as well as to the electric conductivity 1.63 ($\mu\text{S}/\text{cm}$) of Comparative Example 3, which contains propylene glycol belonging to the glycols.

15 Addition of the electrolyte substances increasing the ion concentration in the solution as the additives generally enhances the electric conductivity. In the coolants of Examples 2 and 3, however, the variation in electric conductivity by the addition of the additives is negligible.

20 The coolants of Examples 4 and 7 respectively showed the electric conductivity of 5.3 ($\mu\text{S}/\text{cm}$) and 5.0 ($\mu\text{S}/\text{cm}$). These observed values of electric conductivity were sufficiently close to the electric conductivity 3.46 ($\mu\text{S}/\text{cm}$) of Comparative Example 2, which is the base material of the coolants of Examples 4 and 7.

25 The coolants of Examples 5, 6, 8, and 9 respectively showed the electric conductivity of 3.6 ($\mu\text{S}/\text{cm}$), 3.5 ($\mu\text{S}/\text{cm}$), 3.2 ($\mu\text{S}/\text{cm}$), and 4.4 ($\mu\text{S}/\text{cm}$). These observed values of electric conductivity were sufficiently close to the electric conductivity 3.46 ($\mu\text{S}/\text{cm}$) of Comparative Example 2, which is the base material of the coolants of Examples 5, 6, 8, and 9.

30 The rust-preventive additives used in Examples 4 to 9 are nonionic

substances that are not ionized in the solution, and are theoretically expected to have an identical value of electric conductivity with that of the solvent. The results of the experiment prove that Examples 4 to 9 had the values of electric conductivity practically similar to or sufficiently close to the electric conductivity of the solvent. Namely in the coolants of Examples 4 to 9, the variation in electric conductivity by the addition of the additives is negligible.

The relationship between the quantity of addition of quercetin used as the rust-preventive additive in Example 4 and the electric conductivity is discussed with reference to Fig. 3. Fig. 3 is a graph showing a variation in electric conductivity due to addition of quercetin to a 50% diluted solution of ethylene glycol, with the quantity of addition of quercetin (ppm) as abscissa and the electric conductivity ($\mu\text{S}/\text{cm}$) as ordinate. As clearly understood from the graph of Fig. 3, the electric conductivity is approximately 5 to 6 ($\mu\text{S}/\text{cm}$) against the quantity of addition of quercetin up to 700 ppm. This is sufficiently close to the electric conductivity 3.5 ($\mu\text{S}/\text{cm}$) of the solvent (for example, Comparative Example 2), regardless of the quantity of addition. The electric conductivity continuously increases after the quantity of addition of quercetin exceeds 700 ppm. For example, the observed electric conductivity is about 7 ($\mu\text{S}/\text{cm}$) against the quantity of addition of quercetin equal to 1000 ppm. It is accordingly understood that quercetin, a nonionic substance, shows the sufficiently low electric conductivity, regardless of the quantity of addition and is a favorable rust-preventive additive for the coolant that requires the low electric conductivity.

The electric conductivity of Example 1 was 29.0 ($\mu\text{S}/\text{cm}$), which was higher than the values of electric conductivity of Comparative Examples 2 and 3 (5.01 ($\mu\text{S}/\text{cm}$), 3.46 ($\mu\text{S}/\text{cm}$)). This value was, however, 1/10 of the electric conductivity of Comparative Example 5 and less than 1/100 of the electric conductivity of Comparative Example 1.

In the coolants of Examples 1 to 3, pH is regulated by taking advantage of the acidic and alkaline characteristics of the selected rust-preventive additives. Compared with the technique using a pH regulator, this technique keeps the electric conductivity of the coolant at an extremely low level. The rust-preventive additives included in the coolants of Examples 4 to 9 are neutral nonionic substances, so that the electric conductivity of the coolant can be kept practically similar to the electric conductivity of the solvent without any pH regulation.

The following discussion regards comparison among results of the test for the passivation current density (passivation holding current) ($\mu\text{A}/\text{cm}^2$), which is the electric current passivating a sample metal. The test applied an aluminum material (AC2A) as the sample metal for one electrode and platinum for the other electrode, soaked both the electrodes in each of the coolants enumerated in the table of Fig. 1 (88°C, 300 ml), bubbled the coolant with N_2 at 10 ml/min, and made the coolant undergo deoxidization. The test then measured the value of electric current flowing between the two electrodes. The current density represents the intensity of electric current produced per unit area in the course of electrolysis of the sample metal. In general, the higher current density accelerates dissolution of the sample metal, which means corrosion. In this test, the higher current density represents the higher corrosion rate of the aluminum material.

In Examples 4 to 9 and Comparative Examples 2 to 4 whose observed values are shown in brackets in the table of Fig. 2, 50 ppm of HCO_3^- was added as a supporting electrolyte for the measurement. Addition of 50 ppm of HCO_3^- as the supporting electrolyte causes the dissolved HCO_3^- (ion) to enhance the value of current density.

The measurement was performed in the flow of the air in Examples 1 to 3 and Comparative Examples 1 to 3 and 5.

Example 1 showed the passivation current density of $4.8 (\mu\text{A}/\text{cm}^2)$ in

the flow of N_2 and $2.4 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air. Example 2 showed the passivation current density of $11 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of N_2 and $12 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air. Example 3 showed the passivation current density of $2.4 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of N_2 and $2.4 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air. Example 4, Example 5, and Example 6 respectively showed the passivation current density of $7 \text{ } (\mu\text{A}/\text{cm}^2)$, $15 \text{ } (\mu\text{A}/\text{cm}^2)$, and $16 \text{ } (\mu\text{A}/\text{cm}^2)$. Example 7, Example 8, and Example 9 respectively showed the passivation current density of $16 \text{ } (\mu\text{A}/\text{cm}^2)$, $60 \text{ } (\mu\text{A}/\text{cm}^2)$, and $80 \text{ } (\mu\text{A}/\text{cm}^2)$.

Comparative Example 1, on the other hand, showed the passivation current density of $3.0 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of N_2 and $3.0 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air. Comparative Example 2 showed the passivation current density of $100 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of N_2 and $2.0 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air. Comparative Example 3 showed the passivation current density of $100 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of N_2 and $1.3 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air.

Comparative Example 4 showed the passivation current density of $100 \text{ } (\mu\text{A}/\text{cm}^2)$. Comparative Example 5 showed the passivation current density of $76 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of N_2 and $210 \text{ } (\mu\text{A}/\text{cm}^2)$ in the flow of the air.

The coolants of Examples 1 to 7 are little corrosive against the aluminum material, compared with Comparative Examples 2 and 5.

Especially the coolants of Examples 4 to 7, irrespective of the presence of the supporting electrolyte, show the extremely low passivation current densities. This shows that these coolants are inherently little corrosive against the aluminum material.

The coolants of Examples 8 and 9 show the higher passivation current densities than the coolants of Examples 1 to 7, but are still less corrosive against the aluminum material than the coolants of Comparative Examples 2 and 4. The coolant of Comparative Example 1 without the supporting electrolyte shows the low passivation current density substantially equivalent to those of the coolants of Examples 1 to 3 without the supporting electrolyte. Comparative Example 1, however, has the

extremely high electric conductivity and is thus not suitable for the coolant as discussed previously. Comparative Example 5 has the higher passivation current density and the higher electric conductivity than the coolants of Examples 1 to 3 and is thus not suitable for the coolant.

5 The following discussion regards comparison among the results of the metal corrosion resistance test. The test measured the quantity of corrosion (that is, the decrease in weight per unit area: mg/cm^2) of the aluminum material in each coolant after the aluminum material was left in each coolant heated to 88°C in the flow of the air for 360 hours. The measurement was performed twice in the flow of the air in Examples 1 to 7 and Comparative Examples 1 to 3, 5, and 6, while being performed twice in the flow of N_2 in Examples 1 and 3 and Comparative Example 3. The negative values in the table given as the results of the metal corrosion resistance test mean that the aluminum material was corroded. The positive values mean that the aluminum material was not corroded but some substance was accumulated on the surface of the aluminum material.

Comparative Example 5, which is expected to be most corrosive, had the quantity of corrosion of -0.52 (mg/cm^2) in the first measurement and -0.43 (mg/cm^2) in the second measurement. Comparative Example 2, which is the base material of the respective Examples, had the quantity of corrosion of -0.12 (mg/cm^2) in the first measurement and 0.10 (mg/cm^2) in the second measurement. Comparative Example 3, which includes propylene glycol belonging to the glycols, had the quantity of corrosion of -0.12 (mg/cm^2) in the first measurement and 0.09 (mg/cm^2) in the second measurement.

Example 1, on the other hand, had the quantity of corrosion of 0.01 (mg/cm^2) in the first measurement and -0.01 (mg/cm^2) in the second measurement. Example 2 had the quantity of corrosion of -0.04 (mg/cm^2) in both the first and the second measurements. Example 3 had the quantity of corrosion of 0.04 (mg/cm^2) in the first measurement and 0.15

(mg/cm²) in the second measurement. Example 4 had the quantity of corrosion of -0.02 (mg/cm²) in the first measurement and 0.01 (mg/cm²) in the second measurement. Example 5 had the quantity of corrosion of -0.02 (mg/cm²) in both the first and the second measurements. Example 6
 5 had the quantity of measurement of -0.03 (mg/cm²) in the first measurement and -0.01 (mg/cm²) in the second measurement. Example 7 had the quantity of measurement of 0.00 (mg/cm²) in the first measurement and -0.02 (mg/cm²) in the second measurement.

Examples 1 to 7 have the observed values all significantly lower
 10 than the observed value of Comparative Example 4, and have enhanced corrosion resistance, compared with Comparative Example 2, which is the base material of these Examples.

Comparative Example 6 had the quantity of corrosion of 0.10 (mg/cm²) in both the first and the second measurements. Comparative
 15 Example 1 had the quantity of corrosion of -0.02 (mg/cm²) in the first measurement and 0.03 (mg/cm²) in the second measurement.

As clearly understood from the above comparison with Comparative Examples, the respective Examples had practically equivalent or less quantities of corrosion.

20 The following gives the observed quantities of corrosion in the flow of N₂ in Examples 1 and 3 and Comparative Example 3. Example 1 had the quantity of corrosion of 0.00 (mg/cm²) in the first measurement and -0.01 (mg/cm²) in the second measurement. Example 3 had the quantity of corrosion of 0.04 (mg/cm²) in the first measurement and 0.05 (mg/cm²) in
 25 the second measurement. Comparative Example 3 had the quantity of corrosion of 0.02 (mg/cm²) in the first measurement and 0.04 (mg/cm²) in the second measurement.

These observed quantities of corrosion in the flow of N₂ are compared with those in the flow of the air. Example 1 has substantially
 30 equivalent results, whereas Example 3 has similar results. In

Comparative Example 3, on the other hand, the comparison shows that the flow of N_2 prevents the corrosion. The deoxidization process of blowing an inert gas, such as nitrogen (N_2), decreases the quantity of oxygen dissolved in the coolant and suppresses corrosion of the aluminum material. The deoxidization of the coolant, for example, with the nitrogen gas thus effectively prevents corrosion of the aluminum material, which is used as the material of the cooling circuit.

The above results of the comparison show that the coolant of Comparative Example 6, that is, conventionally used ion exchanged water (pure water), shows the favorable values for the electric conductivity and the quantity of corrosion. Ion exchanged water, however, freezes in the environment below the freezing point. In the case where ion exchanged water is applied for the coolant, an anti-freezing circuit should be provided and continuously driven in fuel cells, which may be placed in the environment below the freezing point. It is, however, difficult to provide the anti-freezing circuit in movable and intermittent-driving fuel cells. Namely ion exchanged water is unsuitable as the coolant for the movable and intermittent-driving fuel cells, which may be placed in the environment below the freezing point.

The coolant of Comparative Example 1, that is, the prior art coolant conventionally used for cooling internal combustion engines, has favorable unfreezing performance and rust resistance but extremely high electric conductivity, and is thus unsuitable as the coolant for cooling a stack of fuel cells, which is required to have low electric conductivity.

The coolants of Comparative Examples 2 and 3, that is, the coolants composed of the base material of Examples 1 to 3 or its equivalence, have favorable electric conductivity and unfreezing performance, but are still unsuitable as the coolant for cooling a stack of fuel cells from the viewpoint of the corrosion resistance (rust resistance).

The above results show that the compositions of Examples 1 to 9

are suitable as the coolant for a stack of fuel cells from the viewpoints of unfreezing performance, rust resistance, electric conductivity, and heat conductivity.

The measurements of pH and electric conductivity described above
 5 were carried out under the condition of 1 atm and 25°C. The
 measurements of metal corrosion resistance and passivation current
 density were carried out under the condition of 1 atm and 88°C. It is
 desirable to apply the additives to set pH in the range of about 6 to 9 and
 the electric conductivity of less than about 100 μ S/cm under the working
 10 conditions, for example, at the pressure of 1 to 1.9 atm and at the
 temperature of -35°C to 100°C.

Although the coolant of Example 3 used acidulous benzotriazole, an
 alkalescent ethanolamine additive may be used to regulate the rust-
 preventive ability, electric conductivity, and pH of the coolant to desired
 15 properties.

In Examples 1 to 9 and Comparative Examples 1 to 3, the freezing
 point was -30°C. In Comparative Examples 5 and 6, the freezing point
 was 0°C.

20 * Second Embodiment:

A second embodiment of the present invention regards a fuel cells
 stack cooling system, which uses each of the coolants of the respective
 Examples according to the first embodiment as the cooling medium, with
 referring to Figs. 4 and 5. Fig. 4 illustrates the structure of the fuel cells
 25 stack cooling system in the second embodiment of the present invention.
 Fig. 5 is a decomposed perspective view showing the stack structure of unit
 cells 20.

A stack 12 of fuel cells 10 is obtained by laying multiple unit cells 20
 one upon another. Each unit cell 20 includes an air electrode 21, a fuel
 30 electrode 22, a matrix (electrolyte) 23 interposed between the air electrode

21 and the fuel electrode 22, and a pair of separators 24 composed of dense carbon and arranged outside the fuel electrode 22 and the air electrode 21. An aluminum cooling separator 30 is arranged on the separator 24 after every heap of multiple layers of the unit cells 20.

5 In this embodiment, the separator 24 is either one of an end separator 40 and a central separator 50. The cooling separator 30 and these separators 40 and 50 are formed as plates having square laminating faces. Coolant apertures 81 and 82 having circular cross section are formed at two different places in the circumference of the end separator 40
10 and the central separator 50 (that is, upper corners in Fig. 5). In the stack of fuel cells, the coolant apertures 81 and 82 form a flow path of the coolant, which passes through the stack in the laminating direction. A pair of gaseous fuel slots 83 and 84 and a pair of oxidizing gas slots 85 and 86 are formed along the respective sides in the circumferential part of the
15 laminating face in each of the three different types of separators. In the stack of fuel cells, the gaseous fuel slots 83 and 84 and the oxidizing gas slots 85 and 86 respectively form a flow path for a hydrogen-containing gaseous fuel and a flow path for an oxygen-containing oxidizing gas, which pass through the stack in the laminating direction.

20 The cooling separators 30 are connected to an external cooling circuit 32 via a coolant flow path. The cooling separators 30 and the external cooling circuit 32 form a cooling circuit 34. A plurality of parallel grooves are formed as ribs 63 connecting the opposing oxidizing gas slots 85 and 86 in one face (the rear face in Fig. 5) of the cooling separator 30.
25 In the stack of fuel cells, the ribs 63 are combined with the adjoining air electrode 21 to form a flow path for the oxidizing gas. A serpentine groove 87 is formed in the other face (the surface in Fig. 5) of the cooling separator 30 to connect the coolant apertures 81 and 82. In the stack of fuel cells, the cooling separator 30 adjoins to the end separator 40, and the groove 87
30 is combined with the flat surface of the end separator 40 to form a flow path

for the coolant.

A plurality of parallel grooves are formed as ribs 62 connecting the opposing gaseous fuel slots 83 and 84 in one face (the surface in Fig. 5) of the end separator 40. In the stack of fuel cells, the ribs 62 are combined
 5 with the adjoining fuel electrode 22 to form a flow path for the gaseous fuel. The other face (the rear face in Fig. 5) of the end separator 40 is flat without any grooves.

A plurality of parallel grooves are also formed as the ribs 62 connecting the opposing gaseous fuel slots 83 and 84 in one face (the
 10 surface in Fig. 5) of the central separator 50. In the stack of fuel cells, the ribs 62 are combined with the adjoining fuel electrode 22 to form a flow path for the gaseous fuel. A plurality of parallel grooves are formed as the ribs 63 connecting the opposing oxidizing gas slots 85 and 86 in the other
 15 face (the rear face in Fig. 5) of the central separator 50. In the stack of fuel cells, the ribs 63 are combined with the adjoining air electrode 21 to form a flow path for the oxidizing gas.

The separators 24 (40 and 50) may be composed of a material having electric conductivity other than dense carbon. A metal like a copper alloy or aluminum alloy may be applied for the separators 24 to
 20 ensure the sufficient rigidity and heat transfer property.

Each of the coolants according to the first embodiment of the present invention (that is, the coolants of Examples 1 to 9) are used for the coolant in the cooling circuit. An inert gas, for example, nitrogen gas, is enclosed together with the coolant in the cooling circuit 34. The air
 25 present in the cooling circuit 34 and oxygen dissolved in the coolant are thus substituted by nitrogen gas to prevent deterioration of the coolant due to the dissolved oxygen. This is proved by the results of various test discussed in the first embodiment of the present invention.

* Third Embodiment:

A third embodiment of the present invention regards a method of manufacturing each of the coolants according to the first embodiment of the present invention with referring to Fig. 6. Fig. 6 schematically illustrates a process flow of manufacturing the coolant according to the first
5 embodiment of the present invention.

The method first mixes ion exchanged water with ethylene glycol to prepare the base material. For example, the method prepares the base material to make the rate of ethylene glycol equal to 50% by weight in a resulting coolant, by taking into account the total quantity of the rust-
10 preventive additive (step 1). The method then prepares the rust-preventive additive as a mixture of an alkaline additive and an acidic additive or the rust-preventive additive of a nonionic substance (step 2). Any of the chemical substances enumerated in the first embodiment of the present invention may be applied for the rust-preventive additive. For
15 example, the rust-preventive additive of Example 1 is prepared by making the rates of triethanolamine and ortho-phosphoric acid respectively equal to 1.0% by weight and 0.1% by weight.

After preparing the base material and the rust-preventive additive, the method mixes the rust-preventive additive with the base material to
20 prepare a solution mixture (step 3). The method subsequently filtrates (decontaminates) the solution mixture through a film of an ion exchange resin to remove the ionized substance from the solution mixture (step 4). The solution mixture decontaminated through the ion exchange resin film is each of the coolants according to the first embodiment of the present
25 invention.

This manufacturing method gives preferable coolants for the stack of fuel cells, which satisfy the required unfreezing performance, rust resistance, electric conductivity, and heat conductivity.

The process of decontamination may use an ion exchange resin
30 film, a fibrous ion exchange resin, or a column filled with particles of an ion

exchange resin, through which the solution to be treated is filtered.

Another applicable procedure stirs the solution mixture of the base material and the rust-preventive agent with an ion exchange resin for a preset time period and makes the solution mixture filtered through a PTFE filter film.

- 5 Prior to the use of the ion exchange resin, it is desirable to treat the ion exchange resin with an acid solution (for example, concentrated hydrochloric acid), so as to remove metal ions adsorbed on the ion exchange resin.

- 10 The above description regards the coolants for fuel cells as the preferable embodiments of the present invention. These embodiments are, however, to be considered in all aspects as illustrative and not restrictive. There may be many modifications, changes, and alterations without departing from the scope or spirit of the main characteristics of the present invention. All changes within the meaning and range of
- 15 equivalency of the claims are therefore intended to be embraced therein.

- The rate of each component in the respective compositions given as the Examples according to the first embodiment of the present invention are only illustrative. For example, the desired unfreezing property, rust resistance, electric conductivity, and heat conductivity can be attained by
- 20 triethanolamine in the range of 0.1 to 3.0% by weight, by ortho-phosphoric acid in the range of 0.1 to 1.0% by weight, by phosphonic acid in the range of 0.001 to 0.01% by weight, and by benzotriazole in the range of 0.1 to 0.6% by weight.

- Some of the above Examples had the value of 6.2 or 8.1 for pH.
- 25 Especially the aluminum material applied for the cooling circuit is not corroded at pH in the range of 6 to 9.

- The construction of the fuel cells stack cooling system discussed above as the second embodiment of the present invention is only illustrative and not restrictive. The cooling system may have any
- 30 construction, as long as the cooling system has any of the coolants

according to the first embodiment of the present invention, which is enclosed with an inert gas and is used as the cooling medium of the cooling circuit.

5 In the embodiments of the present invention discussed above, pH of each coolant is adjusted with the rust-preventive additive on the assumption that the aluminum material is applied for the cooling circuit including cooling plates. Such specification, however, does not restrict the material of the cooling circuit to the aluminum material. In the case of another material, the desired pH should be attained with a rust-preventive
10 additive suitable for the selected material.

AMENDED SHEETS

CLAIMS

1. (Amended) A coolant for fuel cells that is used to cool down fuel cells, comprising:

- 5 a water-containing base material; and
a rust-preventive additive that functions to keep an electric conductivity of said coolant for fuel cells at a low level and to maintain a hydrogen ion exponent of said coolant for fuel cells in a substantially neutral level.

10

2. (Amended) A coolant for fuel cells in accordance with claim 1, wherein the base material is a solution mixture containing a glycol.

3. (Amended) A coolant for fuel cells in accordance with either one
15 of claims 1 and 2, wherein the rust-preventive additive includes at least one of an alkalescent additive and an acidulous additive.

4. (Amended) A coolant for fuel cells in accordance with either one
of claims 1 and 2, wherein the rust-preventive additive includes an
20 alkaline additive and an acidic additive.

5. (Amended) A coolant for fuel cells in accordance with claim 4, wherein the alkaline additive is an ethanolamine series.

25 6. (Amended) A coolant for fuel cells in accordance with claim 5, wherein the ethanolamine series includes triethanolamine, diethanolamine, and monoethanolamine.

7. (Amended) A coolant for fuel cells in accordance with any one of
30 claims 4 to 6, wherein the acidic additive is selected out of the group

AMENDED SHEETS

consisting of triazole compounds, phosphoric acid compounds, and organophosphoric acid compounds.

8. (Amended) A coolant for fuel cells in accordance with any one of
5 claims 1 to 7, wherein the rust-preventive additive causes said coolant for fuel cells to have a hydrogen ion exponent of about 6 to 9.

9. (Amended) A coolant for fuel cells in accordance with any one of
10 claims 1 to 8, wherein the rust-preventive additive causes said coolant for fuel cells to have a low electric conductivity of less than about 100 $\mu\text{S}/\text{cm}$.

10. (Amended) A coolant for fuel cells in accordance with any one
of claims 1 to 9, wherein the rust-preventive additive especially has
rust-preventive performance against aluminum material.

15 11. A coolant in accordance with claim 1, wherein the rust-preventive additive is a nonionic series substance.

12. A coolant in accordance with claim 11, wherein the nonionic
20 series substance includes at least one of a saccharide and a nonionic surfactant.

13. A coolant in accordance with either one of claims 11 and 12,
said coolant is decontaminated by a coolant decontamination system
25 using either one of an ion exchange resin and a chelating resin.

14. A coolant in accordance with any one of claims 1 to 13, said
coolant has undergone deoxidization.

30 15. A method of enclosing a coolant in accordance with any one of

AMENDED SHEETS

claims 1 to 13 in a cooling circuit for a stack of fuel cells, said method comprising the steps of:

deoxidizing said coolant; and

enclosing said deoxidized coolant with an inert gas in said cooling circuit.

- 5 16. A cooling system for a stack of fuel cells, said cooling system comprising:
a coolant in accordance with any one of claims 1 to 13; and
a cooling circuit in which said coolant and an inert gas are enclosed.

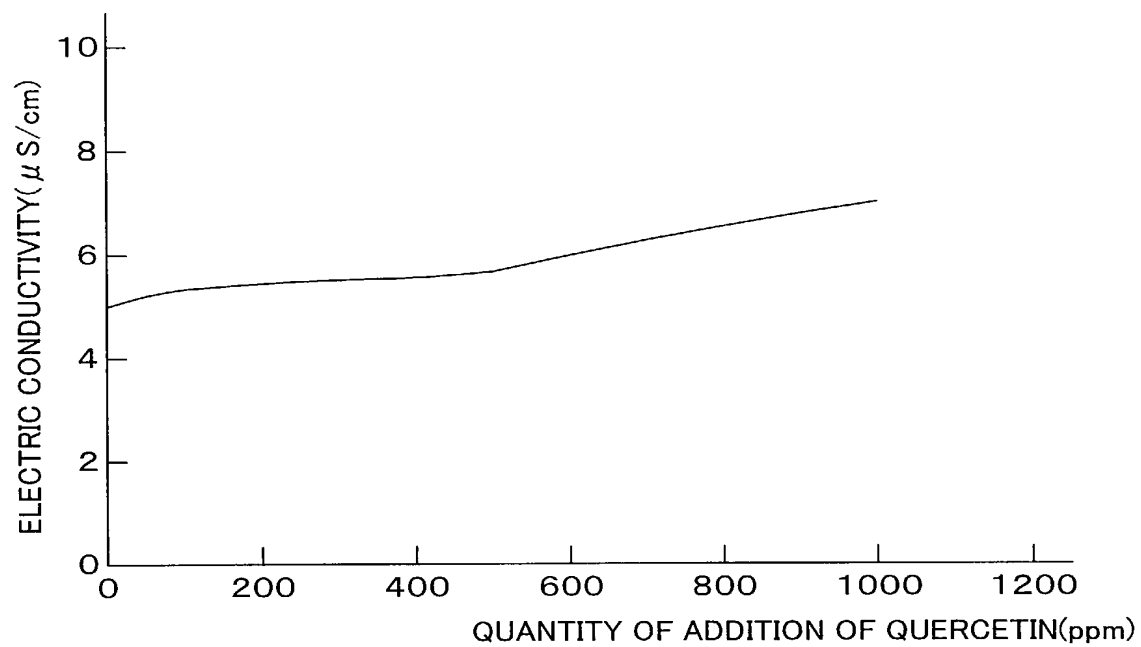
- 10 17. A method of decontaminating a coolant, said method comprising the steps of:
preparing a water-containing base material;
preparing a rust-preventive additive that functions to keep an electric conductivity of said coolant at a low level and to maintain a hydrogen ion exponent of said coolant in a substantially neutral level; and
15 removing deteriorating substances from a solution mixture of the base material and the rust-preventive additive with either one of an ion exchange resin and a chelating resin.

ABSTRACT OF THE DISCLOSURE

A coolant used for cooling down a stack of fuel cells includes: a solution mixture of water and a glycol as base material; and a rust-
5 preventive additive that functions to keep an electric conductivity of the coolant at a low level and to maintain a hydrogen ion exponent of the coolant in a substantially neutral level. The rust-preventive agent includes at least one of an alkaline ethanolamine additive, such as triethanolamine, diethanolamine, or monoethanolamine, and an acidic
10 additive selected among the group consisting of triazole compounds, phosphoric acid compounds, and organophosphoric acid compounds.

Fig. 1

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Comparative Ex. 1	Comparative Ex. 2	Comparative Ex. 3	Comparative Ex. 4	Comparative Ex. 5	Comparative Ex. 6
Base Materials	Ethylene glycol	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	-	-	-	-
	Propylene glycol	-	-	-	-	-	-	-	-	-	-	50.00	-	-	-
	Glycerol	-	-	-	-	-	-	-	-	-	-	-	50.00	-	-
	Ion exchanged water	48.90	49.655	49.90	49.95	49.90	49.90	49.90	49.90	46.78	50.00	50.00	50.00	-	100.00
Additives	Tap water	-	-	-	-	-	-	-	-	-	-	-	-	100.00	-
	Quercetin	-	-	-	0.05	-	-	-	-	-	-	-	-	-	-
	Glucose (Grape sugar)	-	-	-	-	0.10	-	-	-	-	-	-	-	-	-
	Maltose (Malt sugar)	-	-	-	-	-	0.10	0.50	-	-	-	-	-	-	-
	Alkyl glucoside	-	-	-	-	-	-	0.10	-	-	-	-	-	-	-
	POE sorbitan monopalmitate	-	-	-	-	-	-	-	0.10	-	-	-	-	-	-
	Triethanolamine	1.00	0.34	-	-	-	-	-	-	-	-	-	-	-	-
	Ortho-phosphoric acid	0.10	-	-	-	-	-	-	-	0.20	-	-	-	-	-
	Phosphonic acid	-	0.005	-	-	-	-	-	-	-	-	-	-	-	-
	Benzotriazole	-	-	0.10	-	-	-	-	-	0.10	-	-	-	-	-
	Sodium nitrate	-	-	-	-	-	-	-	-	0.10	-	-	-	-	-
	Sodium molybdate	-	-	-	-	-	-	-	-	0.20	-	-	-	-	-
	Sodium benzoate	-	-	-	-	-	-	-	-	2.50	-	-	-	-	-
	Sodium hydroxide	-	-	-	-	-	-	-	-	0.12	-	-	-	-	-
Hydrogen ion exponent (pH)		8.1	8.1	6.2	7~8	7~8	7~8	7~8	7~8	7.3	6.8	6.8	6.8	6~7	6~7

Fig.3

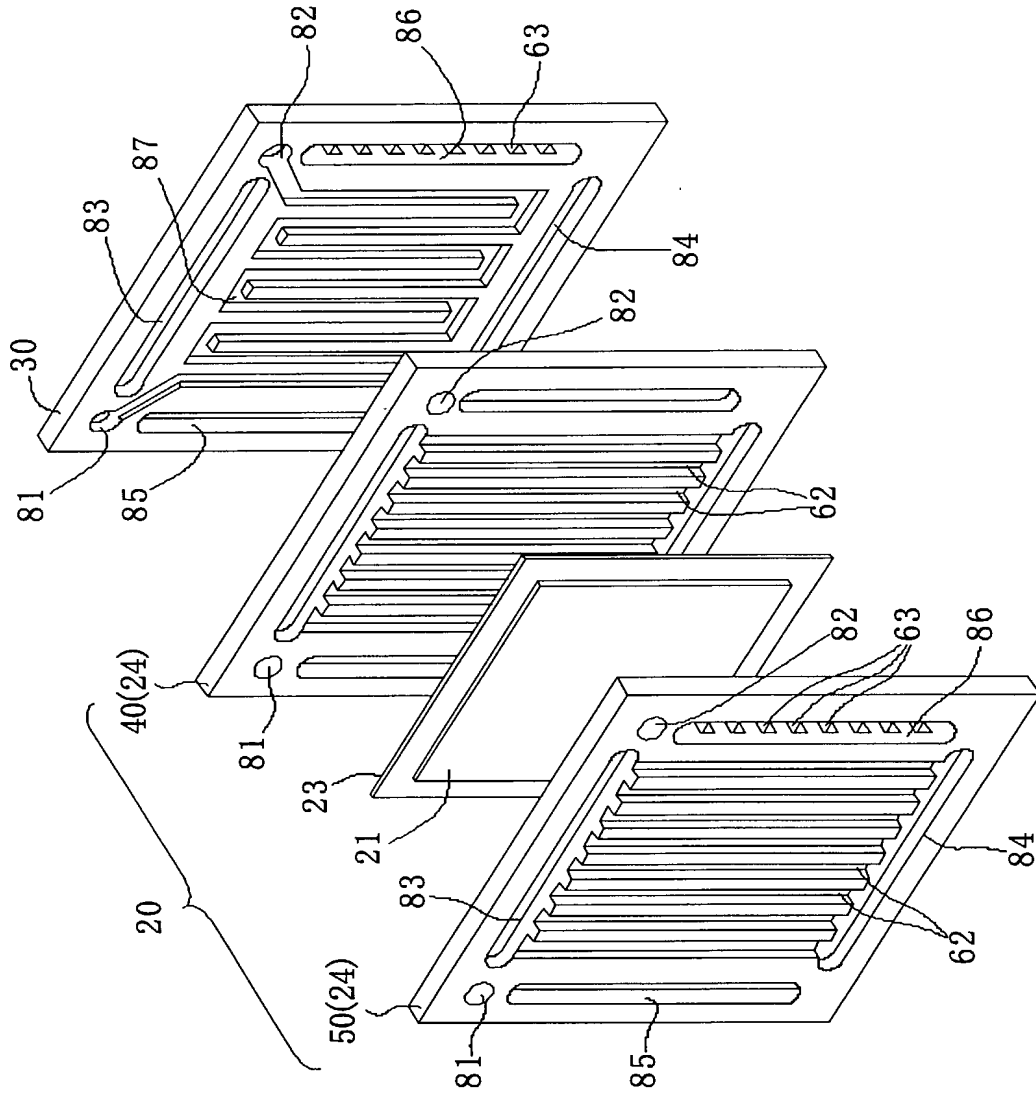


Fig. 4

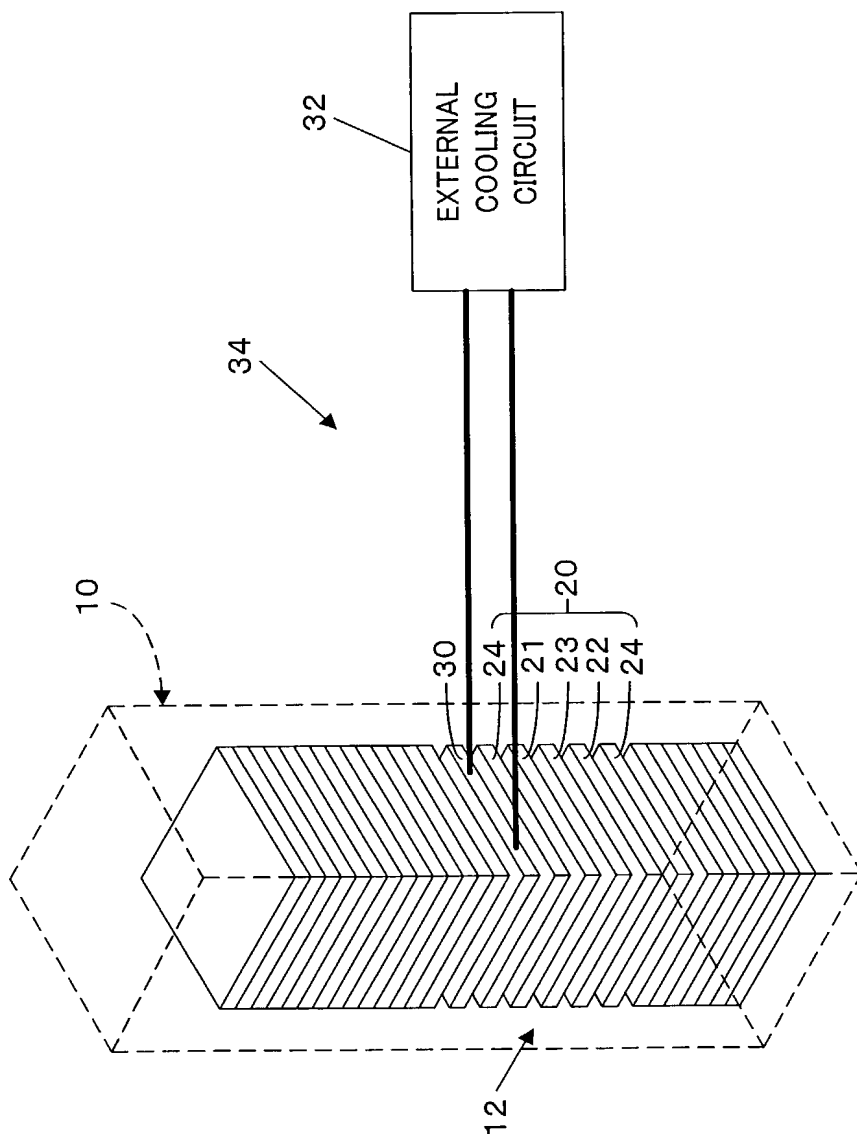
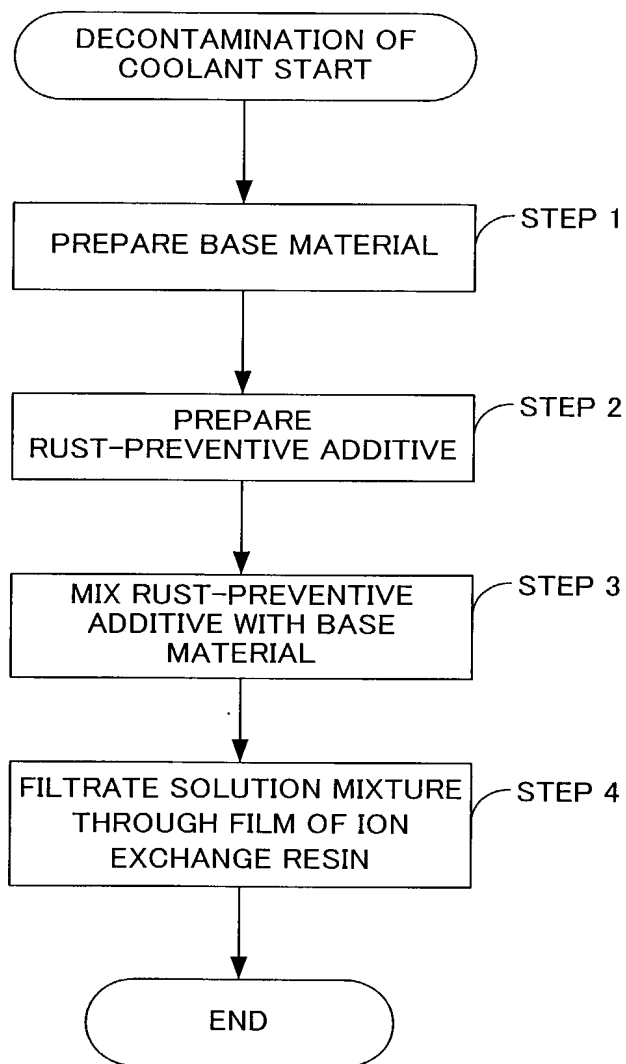


Fig. 5

Fig. 6



Declaration and Power of Attorney For Patent Application**特許出願宣言書及び委任状****Japanese Language Declaration****日本語宣言書**

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は、下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

"COOLANT, METHOD OF ENCLOSING COOLANT, AND COOLING SYSTEM"

上記発明の明細書（下記の欄で×印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ _____に提出され、米国出願番号または特許協定条約
国際出願番号を _____ とし、
(該当する場合) _____ に訂正されました。

☒ was filed on September 27, 2000
as United States Application Number or
PCT International Application Number
PCT/JP00/06683 and was amended on
June 8, 2001 (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条第56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration

(日本語宣言書)

私は、米国法典第35編第119条(a)-(d)項又は365条(b)項に基づき下記の、米国以外の国の少なくとも1ヶ国を指定している特許協力条約365条(a)項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

外国での先行出願

Priority Not Claimed

優先権主張なし

11-273813(P)	Japan	28/September/1999	<input type="checkbox"/>
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願年月日)	
2000-176464(P)	Japan	13/June/2000	<input type="checkbox"/>
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願年月日)	

私は、第35編米国法典119条(e)項に基づいて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119 (e) of any United States provisional application(s) listed below.

(Application No.)	(Filing Date)	(Application No.)	(Filing Date)
(出願番号)	(出願日)	(出願番号)	(出願日)

私は下記の米国法典第35編第120条に基づいて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約第365条(c)に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編第112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37編1章56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365 (c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application:

(Application No.)	(Filing Date)	(Status: Patented, Pending, Abandoned)
(出願番号)	(出願日)	(現況: 特許許可済、係属中、放棄済)
(Application No.)	(Filing Date)	(Status: Patented, Pending, Abandoned)
(出願番号)	(出願日)	(現況: 特許許可済、係属中、放棄済)

私は、私自身の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私が入手した情報と私の信じるところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行えば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration

(日本語宣言書)

委任状： 私は、下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。(弁護士、または代理人の氏名及び登録番号を明記のこと)

8

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

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日付

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Date

Mikito Nishii October 16, 2001

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(Supply similar information and signature for third and subsequent joint inventors.)

Japanese Language Declaration

(日本語宣言書)

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5-00		<u>Satoshi Sugiyama</u>	
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住所	Residence		
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6-00		<u>Kazuhito Yaeda</u>	
第六共同発明者の署名	日付	Sixth inventor's signature	Date
		<u>Kazuhito Yaeda</u>	<u>Nov. 13, 2001</u>
住所	Residence		
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国籍	Citizenship		
	Japan		
郵便の宛先	Post Office Address		
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(第七以降の共同発明者についても同様に記載し、署名をすること) (Supply similar information and signature for seventh and subsequent joint inventors.)			